Essay

Common ground

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The fundamental message of Garrett Hardin's essay 'The Tragedy of the Commons' [1], recently re-visited in these pages by Peter Kareiva [2], is unassailable. If resources are available to all without restraint, they will be over-exploited. That is a simple tenet of population biology, encapsulated in theories of competitive interaction between individuals, and is an explanation for the well-known phenomenon of logistic population growth and of concepts such as that of equilibrium population density. More surprising, perhaps, is the limited extent of our ability to recognise situations where we are exploiting a common resource, and to act appropriately. I want here to draw attention to some commons that are being damaged and on whose maintenance we depend for our sustainability as a species.

If a resource is to be maintained under exploitation, there must be some mechanism limiting the demands placed upon it. In a natural ecosystem, there may be a top-down control, with a predator reducing the population of a prey species below the level at which it can damage its resource base, and reducing competition among individuals. In a human population, we seek to replace such controls — which are ethically unacceptable in civilised societies — by forms of societal regulation, ranging from private ownership to public laws. In order to be able to regulate the exploitation of a resource, however, we need to be able to do two other things first: recognise the existence of a common resource, and measure its capacity and the demands being placed on it, so that we can decide which resources need regulation. Without those actions, we have no means of applying regulation effectively.

The common land of a mediaeval English parish, from which we get the metaphor, was not generally seriously over-exploited, partly because the population was regulated by external factors and partly because there were strong systems of regulation in place. Two miles from where I write is a small and exceptionally diverse nature reserve called Askham Bog. It is a mire, with fenland and other plant communities developed on deep peat in a small valley created by melting ice 15,000 years ago. From the Roman period to the early modern, the bog was a major source of peat, which was cut for fuel by the villagers of the neighbouring parishes of Dringhouses and Acomb [3]. The bye-laws of the Manor of Dringhouses declared in 1637 that "no tenant shall grave or take more turfs [peat blocks] in the moss in one year, but after the custom, viz. for a cottage — one spade graft, and for a messuage two spade grafts. Pain Xs".

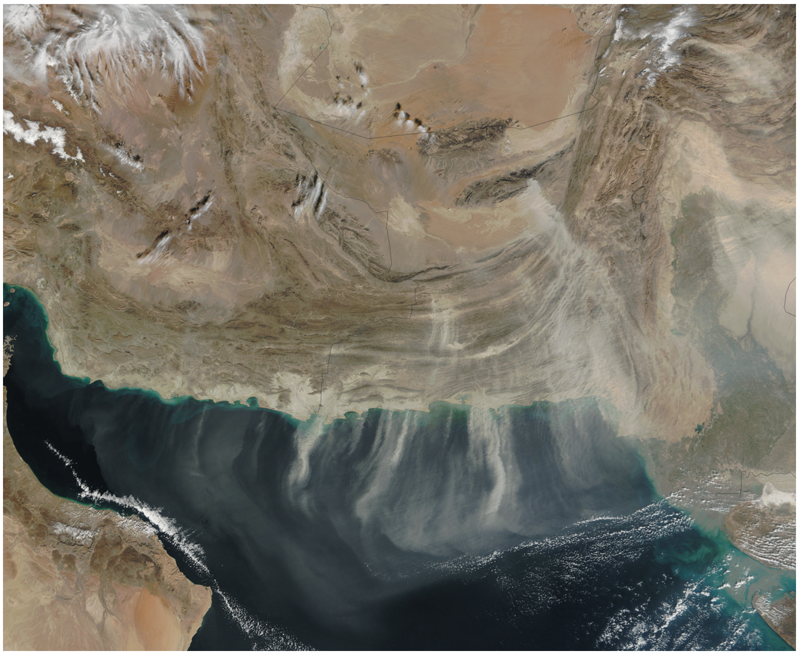
The penalty (pain) or fine of Xs was 10 shillings, or £50 in current value, at the time perhaps two weeks' wages for a labourer. In the nearby Manor of Acomb, the court roll for 1568 records that John Granger was fined IIIs IVd (£33 in modern currency) "for receiving one cart-load of turves more than he ought from the common". These heavy fines show that this was a well-regulated common resource, the sustainability of which was a serious concern to the local community. In this case, however, the regulation was eventually and inevitably insufficient: some time in the 18th century, the supply of peat was exhausted.

Some of the common resources that we exploit are global in extent, and these are the ones for which effective regulation of exploitation is most critical to our survival. Perhaps the most obvious global common is the atmosphere. It is impossible to apply rules of ownership to the atmosphere, and it is such a well-mixed system that impacts on it in one place are inevitably diffused over a wide area, and ultimately throughout the globe. Industrial societies long ago recognised that

One of the ditches crossing Askham Bog near York, probably originally cut in mediaeval times to allow the extraction of peat from the site by boat.. The ditches are shown on the earliest map of the site (1785).

controls over the disposal of waste were essential: restrictions on polluting rivers date back to the nineteenth century and in some cases earlier. It took longer to recognise that air is a global common too, but clean air acts were passed in many countries in the mid-twentieth century, restricting the more blatant forms of air pollution. In the late twentieth century, recognition of the serious potential consequences of ozone destruction led to a further restriction, this time of chlorofluorocarbons. But we have only recently begun to accept that the dumping of greenhouse gases, notably CO_2 as a waste product of combustion and land-use change, need to be similarly regulated: the country that is the major source of this dumping has yet to subscribe to that view.

Most thoughtful people now recognise that the atmosphere, freshwater and seas are global commons, and that their exploitation needs to be regulated, even if implementing such regulation has proved contentious. One global common remains virtually unprotected, however, and that is soil. It is less obvious that soil represents a



Soil blowing from Pakistan into the Arabian Sea on 19 December 2004. (Image courtesy of NASA.)

global common than is the case for air and water. Both the latter are well-mixed systems, where the consequences of local changes are rapidly dispersed. Soil in contrast is a solid medium, in which transport processes are generally slow. Insoluble wastes can be dumped in soil and cause damage only to the local environment. However, the global stock of soil is a common for humanity: we need the food that we can produce only by relying on it. If the ability of the soils in one region to provide food for the local population is damaged, then they will require food imported from elsewhere, throwing a greater strain on the ability of other soils to produce that food.

When soils are damaged or destroyed on a large scale, the consequences spread very wide. The best known case, immortalised by John Steinbeck in his classic novel *The Grapes of Wrath* [4], is of the dustbowl of the American mid-west states in the first part of the 20th century. One such state, Oklahoma, was colonised by European settlers by the bizarre mechanism of a land-rush on 22 April 1889. The European population of the state was 10,000 by the end of that day, 60,000 by the end of April and nearly 400,000 10 years later. The system of arable agriculture that was imposed on the prairie soils was so unsuitable and so unresilient to the period of droughts that started the 20th century, that within one generation the farms collapsed, the soil blew across most of the continent, and most of the farmers became environmental refugees, fleeing to California and elsewhere as the despised Okies [5]. The loss of the soils of Oklahoma was catastrophic for the farmers whose misguided agriculture created the problem, but it affected an entire nation. The welfare of soil, then, is a common responsibility.

If we accept that soil is a global common resource for mankind, we must move to the second stage of the process of regulation of its use: measurement. Here the problems begin. We have reasonably good figures for the global stock of soil, at least for the part that is cultivated, and there is clear evidence that we are currently destroying it faster than it can be created by the slow processes of soil formation. But our data on rates of soil loss are very poor. The global cultivated land area is about 14×10^{12} m^2. At a bulk density of 1.6 t m^{-3}, and assuming a soil depth of 1 m, this area would have 22 000 Gt of soil. We have certainly seriously depleted the organic carbon stock in this soil. It is estimated that the historic loss of soil carbon due to agriculture is 78 ± 12 Gt [6] and the current annual loss rate is perhaps 2.5 Gt. Much of that loss is of organic carbon in soil, rather than of soil itself: soil carbon can therefore decline without there being any marked diminution in soil mass. The current estimate for the global soil carbon stock is ~1500 Gt, but that is for all soils, and perhaps half of the carbon is in uncultivated peats in the northern hemisphere. Agricultural soils typically contain 2–3% carbon even in surface layers, and may therefore have contained only a few hundred Gt of carbon before they were exploited. The historic loss therefore represents a large fraction of the original stock, probably between a third and a half [6].

Data on rates of soil loss by erosion are less adequate. One current estimate of global soil erosion potential is 0.38 mm yr^{-1} [7], which implies an annual rate of loss from cultivated land of ~8 Gt, but that loss is unevenly spread geographically: it is much greater in areas such as southeast Asia than elsewhere. If maintained for 100 years, however, that rate of soil loss implies an average loss of ~5% of agricultural soil. To that must be added another 5% of land lost by salinisation caused by inappropriate agricultural approaches [8], and perhaps 2% to urbanisation [9]. So we have already lost at least 10% of our best soils.

Cultivated soils feed us. Uncultivated soils perform another essential common task: at present, they represent a sink for about a third of the ~8 Gt of carbon that we annually dump in the atmosphere [10]. Without that sink, the rate of increase of atmospheric CO_2 concentration would be twice as great and might already have reached the value above which irreversible climate change will occur. Exactly how the sink is distributed across the world's soils is uncertain, but most of the carbon is stored in the peat soils of the northern hemisphere. Alarmingly, and as predicted because of the effect of rising temperature on decomposition processes and because soils have a finite capacity for carbon storage, there is evidence that soils that were formerly carbon sinks are now becoming carbon sources [11]. If we lose the global soil carbon sink, prospects for controlling climate change will be much bleaker.

Among the global commons, soil resembles the sea and freshwater more than the atmosphere, in that it is also home to an exceptional diversity of organisms. Loss of soil therefore also represents loss of biodiversity, but how much is not known. Soil is one of the principal habitats for several highly diverse but poorly characterised groups, notably bacteria, fungi and nematodes [12]. Single site studies suggest that bacterial diversity is locally very high, with 500–5000 types estimated for a single field at Sourhope in Scotland [13], or even as many as 10,000 types suggested as a typical figure per gram of soil [14].

Leaving aside the difficult question of what represents a bacterial species, the major uncertainty is the extent to which one can extrapolate studies such as these to larger geographical scales. Beijerinck [15] declared that “everything is everywhere; the environment selects”, and microbiologists have assumed since then that there is no such discipline as microbial biogeography. If that is true, then soil loss is of no concern from the standpoint of biodiversity conservation, as even a small remnant of the global soil habitat will suffice to accommodate all known types.

There is, however, increasing evidence that microbes do have biogeography. The recent demonstration of a taxon–area relationship for bacteria in a salt marsh [16] shows that one sample of soil is not representative of another: as geographic scale increases, so does the number of species, albeit more slowly than for other taxonomic groups. That finding is not in itself inconsistent with Beijerinck’s dictum: a wider spread of samples will include more environmental variation and hence more species even if dispersal is an over-riding force. Even so, it seems likely that soil loss does lead to biodiversity loss, but on what scale we cannot yet say. It is remarkable that there are no known extinct microbes (except perhaps for the smallpox virus), a fact that probably tells us more about our ignorance of the microbial world than about rates of extinction.

Can we stop treating soil as simply the ground beneath our feet? The most obvious damage to soil is due to inappropriate agricultural techniques being applied to soils. Agriculture is inherently damaging to soil, involving removing from it resources that can often not be replaced, notably phosphate [17]. Most agricultural systems rely on annual crops and hence on ploughing, which breaks up root mats and exposes the soil to the erosive force of wind and water. Effective education programmes and political reform can often mitigate much of that damage.

The more subtle damage is caused by rising temperatures and changes to rainfall pattern that are preventing soil from performing one of its most vital global services, namely carbon sequestration. We have had enough knowledge for some time now to identify the world’s soil as a global common and we can measure the rates of exploitation sufficiently to know that regulation is required. It seems unlikely that so uncharismatic a thing as soil can benefit from the perceptual shifts advocated by Paul and Anne Ehrlich [18]; as Kareiva [2] says, Hardin’s “mutual coercion, mutually agreed upon” seems likely to be necessary for at least some common resources for a while yet.

References

1. Hardin, G. (1968). The tragedy of the commons. Science *162*, 1243–1248.
2. Kareiva, P. (2005). Is the key to conservation changing ethical values or policing unethical behaviour? Curr. Biol. *15*, R40-R42.
3. Fitter, A.H., and Smith, C.J. (1979). *A Wood in Ascam*. Ebor Press: York.
4. Steinbeck, J. (1939). *The Grapes of Wrath*. Viking Press, New York.
5. Hyams, E. (1952). *Soil and Civilization*. John Murray, London.
6. Lal, R., Griffin, M., Apt, J., Lave, L., and Morgan, M.G. (2004). Managing soil carbon. Science *304*, 393.
7. Yang, D.W., Kanae, S., Oki, T., Koike, T., and Musiake, K. (2003). Global potential soil erosion with reference to land use and climate changes. Hydrol. Process. *17*, 2913–2928.
8. Metternicht, G.I., and Zinck, J.A. (2003). Remote sensing of soil salinity: potentials and constraints. Remote Sensing of Environment *85*, 1–20.
9. Svirejeva-Hopkins, A., Schnellnhuber, H.J., and Pomaz, V.L. (2004). Urbanised territories as a specific component of the global carbon cycle. Ecol. Modell. *173*, 295–312.
10. Grace, J. (2004). Understanding and managing the global carbon cycle. J. Ecol. *92*, 189–202.
11. Turetsky, M.R., Wieder, R.K., and Vitt, D.H. (2002). Boreal peatland C fluxes under varying permafrost regimes. Soil Biol. Biochem. *34*, 907–912.
12. Fitter, A.H. (2005). Darkness visible: reflections on underground ecology. J. Ecology, in press.
13. McCaig, A., Glover, L.A., and Prosser, J.I. (2001). Numerical analysis of grassland bacterial community structure under different land management regimens by using 16*S* ribosomal DNA sequence data and denaturing gradient gel electrophoresis banding patterns. Appl. Environ. Microbiol. *67*, 4554–4559.
14. Torsvik, V., Ovreas, L., and Thingstad, T.F. (2002). Prokaryotic diversity - Magnitude, dynamics, and controlling factors. Science *296*, 1064–1066.
15. Beijerinck, M.W. (1913). De infusies en de ontdekking der backteriën. *In* Jaarboek van de Koninklijke Akademie voor Wetenschappen. Müller, Amsterdam, The Netherlands.
16. Horner-Devine, M., Lage, M., Hughes, J.B., and Bohannan, B.J.M. (2004). A taxa-area relationship for bacteria. Nature *432*, 750–753.
17. Newman, E.I. (1997). Phosphorus balance of contrasting farm systems, past and present. Can food production be sustainable? J. Appl. Ecol. *34*, 1334–1347.
18. Ehrlich, P., and Ehrlich, A. (2004). *One with Nineveh*. Washington, Covelo, London: Island Press.

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